AGRICULTURAL GEOLOGY

OF

INDIA

(Second Edition)

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PREFACE.

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There is no book on Agricultural Geology published so far, which will satisfy the needs of a student of Indian Agriculture. He can study the minerals and rocks as also the agencies which form them and disintegrate them from books on general geology ; he can study the formation of soils from books on Agricultural Chemistry and can study Indian rock-formations from books on Indian Geology, but there is no book which gives the necessary information from these three types of books. My experience in teaching Agricultural Geology for over 18 years has enabled me to put this information together in one place to satisfy the needs of a student of Indian Agriculture. I have tried to be as brief as possible without sacrificing any important point. This small book is not an attempt to publish anything original but is an attempt to remove a long—felt want of a book on Agricultural Geology for the use of Indian students.

The books consulted are mentioned in the Bibliography and I feel it my duty to acknowledge my indebtedness to the authors of those books.

My sincere thanks are due to my friend Prof. N. V. Kanitkar for going through the manuscript and the proof and making valuable suggestions.

My thanks are also due to my friend Mr. V. N. Gokhaie, Lecturer at the Poona Agricultural College and Mr D. B. Guzdar, for their help in taking Photos.

POONA.
25 November 1925

D. L. SAHASRABUDDHE.

Preface to the Second Edition.

The first two chapters have been enlarged and re-written. A small addition has been made to the third and the fourth chapters giving hints on the identification of minerals and rocks. The rest of the chapters are mere reprints of the first edition.

Poona
25th May 1929 } D. L. SAHASRABUDDHE.

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PLATES AND MAP.

The Ghataprabha falls near Gokak (Belgaon District.)

Agricultural Geology of India.

CHAPTER I.

INTRODUCTION.

Geology. Geology as a science is of recent origin. It proposes to study the history of the earth from the beginning of its existence to the present time. It includes the study not merely of the rocky material but also of the remnants of plants and animals found imbedded in the rocks of the earth. These remnants belong to plants and animals that inhabited the earth at different stages. They show the changes which the plants and animals have undergone in reaching their present condition. In order to understand clearly what changes must have taken place on the solid layer of the earth-crust in ages gone by we must study the changes which are taking place to-day because "the study of the present is the key to the past". It is hence that geology includes the study of the various agencies which bring about changes on the earth-crust.

Its importance to Agriculture. Geology can be studied from several points of view, such as the chemical, biological, engineering or agricultural. The subject of geology is of importance to agriculture in as much as it deals with the formation and decomposition of minerals and rocks from which soils are derived. All

the agricultural lands are formed from the various rocky formations of the earth and it is therefore essential for the scientific study of the soils to understand fully the formation and composition of the rocks and of the minerals of which they are made up, the agencies which bring about decomposition and the products of decomposition.

Origin of the earth.

In studying geology it is important to get some idea about the origin of the earth and its present condition. In recent years precise methods of inquiry, especially the use of the spectroscope to the study of the stars have helped to confirm the old *nebular hypothesis.* According to this hypothesis, the solar system existed at one time as a nebula—a cloudy incandescent mass of matter. This nebula extended at least as far as the outermost planet of the solar system. It was made up of incandescent vapours or gases. Due to the process of cooling and condensing various rings were thrown out. These rings on disruption and further condensation became what we call the planets of our solar system. The planets themselves went on condensing and threw off rings as seen at present in the case of saturn. The rings of the other planets broke up and formed satellites like our moon. The central incandescent mass left yet is the sun. It seems that the materials in the nebula arranged themselves according to their densities, the lightest material being outside and the heaviest occupying the inside portion. This is seen from the densities of the planets. If the density of the earth is taken as one then that of mercury which is nearest the sun is 1·12 while the densities of the planets

outside the orbit of the earth are less than one and the density of neptune, the outermost planet is only 0·16.

The present condition of the earth.

The outside of the earth is now quite-cool; but abundant proof exists to show that the interior of the earth is very hot. A large proportion of the planet is hotter than molten iron. The earth must have been once in the state of incandescent vapour and it has ever since that time been cooling and contracting. Its present shape affords strong presumption in favour of the opinion that the globe was once in a plastic condition. The flattening at the poles and bulging at the equator, is just the shape which a plastic mass would assume under the influence of the movement of rotation, imparted to it when detached from the parent nebula.

The three spheres.

The earth consists of three spheres:—(1) The atmosphere which forms a gaseous envelope round the earth, (2) below the atmosphere is the second envelope called the hydrosphere which consists of water and (3) the lithosphere, a central globe cool and solid on its surface but very hot inside.

From the arrangement of the spheres it will be seen that our earth is very much what, according to the nebular hypothesis it might be expected to be. On the outside is the lightest layer of gases, below it is the layer of water which is denser than the gases but lighter than the rocks. The rocks themselves have an average density from two to three but the density of the globe is five and a half. Hence we may infer that the inner portion of the

lithosphere consists of heavy materials, and may be metallic. There is thus an evidence of arrangement of the planet's materials in successive spherical shells according to their densities.

The limits between the solid, liquid and gaseous portions of the earh are not absolute. Water is found penetrating rocks and also as vapour in the atmosphere. The gases of the atmosphere are found dissolved in water and also imprisoned in rocks of the solid earth. Particles of the solid portion are found hanging in a finely divided state in the atmosphere and in suspension in water.

It is supposed that the present gaseous and liquid envelopes of the planet form only a portion of the original mass of gas and water. Fully a half of the outer solid shell of the earth consists of oxygen which once existed in the atmosphere. The water also has, to a great extent been absorbed by minerals. It has been estimated that already one-third of the whole mass of the ocean has been absorbed. Eventually the surface of the planet will probably resemble that of the moon—a globe without air or water or life of any kind.

The Atmosphere.

The atmosphere extends from the surface of the earth to a distance which has been variously estimated, from 45 to 200 miles. The pressure exerted by the atmosphere at the sea—level is $14\frac{3}{4}$ pounds every square inch. The atmosphere consists of a mixture of gases, the chief of which are nitorgen and oxygen. Besides these there are variable quantities of aqueous vapour, carbon dioxide, argon and small quantities of hydrogen, ammonia, ozone and nitric acid.

The Hydrosphere.

The hydrosphere consists of the oceanic waters which cover nearly three-fourths of the earth's surface. All the oceans are connected at the surface but they have distinct basins.

Sea-level.

The surface of the sea is in sharp contrast with that of the land in that the former seems to be level. It is the datum plane from which all elevations on land are measured. It is called the sea-level.

Depth and volume of water.

Average depth of the ocean is estimated to be about two and one-half miles, the greatest known depth being nearly six miles. The average volume of sea-water is nearly fifteen times the volume of land above sea-level. If the surface of the lithosphere is brought to a common level by planing down all continental platforms and building up the deep parts of the ocean basins the oceanic water will cover the whole of the earth to a depth of nearly two miles.

Mineral matter in solution.

There is a good deal of mineral matter in sea-water. Whatever might have been the original composition of the sea water it has for ages together received mineral matter in solution from the land and so sea-water contains more or less every substance which the terestrial water can remove from land. The average proportion of saline constituents in the oceanic waters far away from land is three and a half percent. If all the mineral matter now in solution in the sea were taken out of it, its aggregate volume would be equal to about one-fifth of the volume of all lands now above the sea-level.

Within the gaseous and watery envelopes lies the inner solid globe. The only portion of it which rising above the sea, is visible to us and forms what we term land, occupies a little more than one-fourth of the total surface of the globe. The land above the sea-level is chiefly in the northern hemisphere and is in large masses which taper southwards to about half the distance between the equator and the south pole.

Lithosphere.

'Earth crust' is a term used to denote the upper or outer cool solid layer of the earth's mass which is accessible to human observation and in which lie the chief materials of geological investigation. The thickness of this layer has been estimated to be somewhere between 10 and 20 miles.

Earth-crust.

The interior of the earth is very hot as is indicated by the volcanoes and hot springs. It has also been estimated that for every 60 feet deep we go, there is an increase of 1°F. in temperature. If this rate continues regularly it would give at a depth of 25 miles a temperature sufficient to melt almost any rock at atmospheric pressure.

Interior of the earth.

About the conditions of the earth's interior different views are held. According to one theory the interior of the earth is in a molten state and is surrounded by a solid crust. This view is supported first by the fact that the interior of the earth at a depth of 20 miles is so hot as to have any rock in a molten condition and secondly by the presence of the volcanoes which obtain their molten material from the interior of the earth. Some hold the view that a thin solid crust on a liquid below would have been

Theories about the internal condition.

drawn out by the influence of the moon and the sun. They say that the earth is solid throughout. Although it is hot inside the pressure from above has kept it in a solid state. When from any cause this pressure is relieved internal material becomes liquified locally and gives origin to volcanoes. There are others who think that there is a thin viscous intermediate stratum, reposing on a solid core, and covered by a solid crust. The crust, according to this theory, is solid because it is already cooled, the intermediate molten stratum exists where the downward pressure is insufficent to prevent liquifaction, and the nucleus is kept solid by the excessive pressure at great depths. Finally there is a fourth theory, according to which the earth is a globe of gas, enveloped first by an inner molten layer and next by an outer solid crust. For all purposes of geological study the first theory is the most satisfactory.

Divisions and scope of each division.

Geology may be divided into two main divisions :— Physical geology and Historical geology. Physical geology treats of the origin, composition, and arrangement of the materials of the earth-crust, and Historical geology deals with the past conditions and aspects of the globe, and of the life with which its lands and waters have been successively peopled. Each of these divisions is further divided into sections. The Physical geology includes Dynamical geology and Petrological geology. Dynamical geology treats of the agencies concerned in the formation, elevation and degradation of rockmass. Petrological geology deals with the composition and arrangement of rocks.

Historical geology includes Palæontology and Stratigraphy. Palæontology deals with the animals and plants found as fossils in the rocks, while stratigraphical geology is devoted to the description of the various geological formations and the past conditions of the surface of the globe.

Treatment of the subject in the book.

In studying the formation of soils we have to study the composition of minerals and rocks and the action of the various agencies on them. For a clear understanding it is better to study in the first place the action of the agencies independently of the study of the minerals and rocks. The chapters of this book are so arranged that we first of all study the action of the various agencies and then the composition of important minerals and rocks. Then comes a chapter on the rock systems of India. This is followed by a chapter on the formation of soils. The last two chapters deal with the soils of India and those of the Bombay Presidency.

CHAPTER II.

AGENCIES WHICH FORM AND DISINTEGRATE ROCKS.

Dynamical geology treats of the agencies concerned in the formation, elevation and disintegration of rock masses.

Agencios.

The agencies may be divided into two classes, the external or the outer agencies such as air, water, and life and internal or inner agencies such as volcanoes, earthquakes and crust-movement.

Air.

The air envelopes the earth on every side; acts mechanically by its currents of wind and chemically by the gases of which it is composed.

Mechanical Action.

Changes of temperature have important effects on rocks and soils. In dry climates where the daily range of temperature is excessive as in Sahara and other deserts, the alteration in expansion and contraction of the surface rocks is so great as to break them into small pieces and finally to reduce them to fine particles. Movements of the atmosphere cause winds and the winds have destructive, preservative and reproductive actions. Winds act destructively upon rocks both by the actual pressure exerted and also by hurling rock fragments, against them. Winds also blow and drift-about all loose materials carry-

ing them from one place and piling them at another.

Examples of the destructive action of wind are :—

1. In some parts of the Nile-delta 8 feet of soil is swept away in 2600 years or nearly 4 inches in 100 years.
2. Foundations of buildings are laid bare as in North China.
3. Houses and chimneys are blown up.
4. Scooping action of stones kept in gyration helps in grinding down rocks.

Growth of dust on ancient monuments and cities is a good example of the preservative action. Archeaological Departments publish accounts of temples and cities buried under accumulations of dust, sand and other deposits.

Examples of reproductive action :—

1. In central Asia fine yellow earth carried high in air settles slowly on everything. In Khotan it increases fertility of land.
2. Loess is said to have its origin from the action of winds. It is a yellowish dust deposit spread over the central part of Europe and Asia, extending from Germany to China. The loess material is found in some places even in the Punjab.
3. Sand hills or dunes, as they are many times called, are formed by winds, blowing upon sand and driving and piling it into heaps and

ridges. The sand hills are found along coast-lines of oceans or large lakes where sandy shores are exposed to drying heat and wind. Similar effects are produced in the sandy deserts of Sahara, Arabia &c.

On the Malabar coast sand dunes are common. In the northern portion of the western coast, near about Bombay, no sand hills have been noticed, but further north in Surat, Broach, Kathiawar and Cutch blown sand is found in several places. Sand dunes are frequently found on the banks of such rivers as the Godavari, Krishna and Cauvery. The Rajputana desert is one wide expanse of windblown sand. The prevailing winds have heaped up the sands in a well marked series of ridges which resemble magnified wind ripples.

Chemical action.

Many rocks contain lower oxides of metals. These on exposure to air combine with additional oxygen. In so doing they alter their volume and change their colour, the first aids in breaking up the rock. Air with water oxidises metallic sulphides. The carbon dioxide of the air acting with water brings about several changes which are attirbuted to water. Solution and hydration are also actions which may be considered here or under water. The effect of the combined action of these is to bring about changes in the rocky material especially on the surface of rocks.

Weathering.

Weathering includes all the actions of the various agents and it means the total combined effect of all the meteoric agencies in changing a mineral or a rock. The weathering action is

mostly chemical although many of the processes of weathering are mainly physical or mechanical. Weathering invariably leads to dis-integration of the surface but it does not necessarily always mean disintegration. A sandstone may, on exposure, harden as an effect of weathering. Laterite which is a very soft rock, when freshly dug out, hardens on exposure because the total effect of the various agencies, is the change in that direction. In humid and temperate climates weathering is caused by rain and sunshine. The rain wets and the sunshine dries the rock and it ultimately falls to powder. In a cold country weathering is caused by frost while in hot arid regions the alternate changes in temperature causing contraction and expansion, are the chief causes of weathering. Notwithstanding the exceptions given above the invariable effect of weathering is to disintegrate and powder the rock, to alter the composition of the rock as a whole and of individual particles and thus ultimately turn it into crumpled material and soil.

Water.

Water brings about two kinds of changes upon the surface of the earth. (1) It acts chemically not only on the surface but also when it sinks under ground. (2) It acts mechanically by washing away loose material and depositing it in oceans, lakes or on the river banks &c.

Chemical action.

Chemical action of water is the same as described under air. Rain water dissolves gases from the atmosphere on its way to the earth's surface. One litre or 1000 cc. of rain water contains on an average 25 cc. of air. The composition of this dissolved air shows 64 percent of nitrogen, 33 percent of oxygen

and 1·77 percent of carbon dioxide, besides traces of ammonia, nitric acid &c. Rain water also contains suspended impurities consisting of inorganic particles, organic dust and living germs. So the rain brings not only water but also fertilising material. The chemical changes brought about by water and air are given below.

(1) *Oxidation* :—We often find a crust on the surface of rock exposed to rain and air. This crust thickens and then slowly gets separated from the rock below to be ultimately crushed and removed. The formation of the crust changes the original colour of the rocks which become yellowish brownish or reddish. All this is due to oxidation of iron and manganese oxides &c.

(2) *Deoxidation* :—Organic matter brought down by rain water as also that which accumulates in the soil is the chief cause of deoxidation. Higher oxides are reduced to lower oxides. Deoxidation changes sulphates to sulphides.

(3) *Formation of carbonates* :—The carbon dioxide which is collected by the rain water from the atmosphere serves to attack solid lime stone rock. The insoluble calcium carbonate is turned into soluble calcium bicarbonate and carried away by streams. When the water is exposed in thin layers the carbon dioxide goes off and the calcium carbonate is again deposited as an insoluble material.

(4) *Hydration* :—Some minerals and compounds absorb water and hold it fast as if in chemical combination with it. This change is known as hydration. The absorption of water increases the volume of the mass

which may cause local uplifts. Anhydrite on changing to gypsum increases in volume to the extent of about 33 percent.

(5) *Solution* :—several substances are soluble in water and hence they are found in most waters. There are others which get dissolved under high pressure and temperature while there are still others that get dissolved with the help of carbon dioxide &c.

Mechanical action.

Mechanically water acts in various ways. It loosens rocks, attacks them, and carries away broken material to be deposited again. When the rain water comes down, a part of it evaporates back into the air, a part sinks into the ground and the rest ot the water flows towards the ocean in the form of rivers.

Underground Water.

Underground water is found forming layers in alluvial lands as in Gujerat, while it flows through fissures and cracks in hard rocks like the Deccan trap. In alluvial tracts the water goes down and is held on an impervious layer of clay or lime and sand and there are several such layers one below the other. If the water forming the first layer is brackish or not sufficient in quantity the impervious layer may be bored through to reach the second lower layer. The water from the lower layer mixes with water above. This may improve the well water in quality and quantity also. In the hard rocks the important point in digging wells is to strike water bearing strata. Water-finder machines have been found to be very useful in locating water bearing fissures. The machines, however, must be used by experienced men to

get, correct results. They give indications which can be interpreted in the light of the experience of the workers.

Underground water may some times flow down in such a way that it finds itself in a porous material between impervious layers both above and below. The water accumulates in such places under pressure. If a whole is bored through the upper impervious rock the locked up water rushes up and begins to flow. This is kuown as an *Artesian well.* Suitable conditions for artesian wells are not common in India. Alluvial deposits of Pondicherri yield artesian water. At Lucknow a bore 1189 feet deep gave water which flowed over the top of the casing which was 24 feet above the level of the surrounding plane. There are artesian waters in Baluchistan. In Gujerat artesian water was struck at Navasari at a depth of 150 feet. At Viramgaon and Mahi also artesian water was struck.

Springs.

Underground water may come out in the form of springs. Ordinarily spring-waters have temperature somewhere near the temperature of the surrounding air. But there are some springs which derive their supply from melting ice and therefore have low temperatures. While there are other springs that have higher temperature than that of the air. These are called hot springs. There are many hot springs along the Bombay coast. The hot springs found in the Ratnagiri and Thana districts vary in temperature from 96° F to 150° F. In Sind also there are hot springs. The Mangho Peer spring which is 10 miles to the north of Karachi is perhaps the hottest in Sind. Its temperature

is about 140°F. The hot spring at Laki has a large amount of sulphurreted hydrogen issuing from it. At Gangotri, the source of the Ganges, there is a well-known hot spring. At Manikaran the temperature of the spring water is at boiling point and people cook their rice in the jets of water issuing. The springs may flow the whole year round or they may flow only during a perticular season when they are called seasonal. Such springs flow during the rainyseason or even for sometime after but get dry in the hot summer. There are some springs which flow for some period in any time of the year and then they disappear and may begin to flow again after some days or months. Such springs are called *intermittent springs*. The springs at Rajapur are of this nature. The days for which the flow of these springs continued between 1883 and 1913 varied from 16 to 68 days and the dry period varied from 368 to 1189 days.

The amount of dissolved mineral matter in ordinary drinking water does not exceed 0·5 or at the most 1·0 gramme per litre; the best waters contain less. The amount of organic matter should not exceed 0·005 or 0·01 gramme per litre in wholesome drinking water. When spring waters contain large quantities of salts they are known as mineral springs. According to the prominent salt present they are further designated as calcareous, ferruginous, bitter, medicinal &c. The medicinal springs are believed to have curative effects in different diseases. Many such springs are recognised by medical men. In the Sholapur district there are some waters which are bitter. They contain magnesium and sodium sulphates. Several people flock to these springs to get cure.

The geological work of the underground waters is to remove rocky material from one place to another either chemically or mechanically, to form tunnels and passages, form mineral veins, change composition of minerals, replace fossils molecule by molecule &c.

Rivers. Rivers are the natural drains of land surface. They carry to the oceans not only vast quantities of water but also large quantities of material worn off the land. The waters of the rivers are derived partly from rain and partly from springs and in some cases from melted ice. Average flow of rivers is 1·25 miles an hour, while the fastest is 20 miles. Rivers having a slope above 10 inches in a mile are not navigable. The river waters act both chemically and mechanically on the rocks. Huge quantities of materials are dissolved by the chemical action. On an average 30 parts of soluble salts may be found in 100,000 parts of river waters. In the mechanical action of river are included (1) transport of suspended material, (2) eroding or excavating action and (3) depositing of the sediment from water on banks or in lakes and oceans.

The Elbe (Austria) river was found to carry the following quantities in one year as estimated in 1866 Geikie's Text Book of Geology):—

547,140,000	killogrammes, suspended matter,
652,680,000	killogrammes, dissolved matter, containing among others
140,380,000	killogrammes, lime,
54,520,000	killogrammes, potash,
1,500,000	killogrammes phosphoric acid.

The Mula river near Poona, was found to carry in one day in the rainy season of 1910 the following quantities.

223, 311 pounds in suspension,
334, 966 pounds in solution,
The dissolved substances consisted of
182,370 pounds, calcium carbonate,
89,324 pounds sodium chloride,
37,218 pounds, sodium sulphate
26,056 pounds calcium sulphate.

The excavating or destructive action of the river water is active when there are suspended materials. Mere volume and rapidity of current, will not cause much erosion of the channel of a stream unless sediment is present in the water. Rivers starting from lakes have generally very little of suspended matter and therefore they do not show action of erosion. The excavating action is well demonstrated by the existence of pot-holes, cutting of the river banks and beds and by the water-falls.

Abrupt change in the character of the rocks of river channel may give rise to a water-fall. A water-fall may occur because the water of a river may happen to pass over an already existing precipitous escarpment or it may pass from a hard rock formation to a soft rock formation and produce an escarpment by excavating the soft rock and then continue falling down from the hard to the soft rock. Sometimes waterfalls may occur by the removal or falling down of stratified rocks along lines of their joints. The wellknown Nigara waterfall of America is horse-shoe shaped, has a depth of about 300 feet, width 200 to 400 yards and the length of the gorge

(as the shoe shaped appearance is called) cut into the rock by water is about 7 miles. Depths of some of the Indian waterfalls are :—

The Narbada falls at Jubbulpore 50ft.
The Ghataprabha falls at Gokak 180ft.
The Cauvery falls in Mysore 300ft.
The Gersappa falls in Kanara. 900ft.

The reproductive action of rivers is shown by the deposits at the foot of the hills, on the banks of rivers, in lakes, in forming bars and deltas, and finally in the seas along the coast lines. Any agency that reduces the speed of the current of river waters causes deposition of silt. Where the river joins the sea sometimes huge quantities of silt are accumulated. These are driven towards the sea by the rivers and the sea throws them back at the mouth of the rivers. These become obstructions to navigation and are hence called bars. Rivers many times split up into branches to go round the bar to meet the sea and ultimately develop large areas of deposits known as deltas. The deltas are triangular shaped with their bases towards the seas and apices where the rivers split into branches. The delta of the Nile has a seaward border of 180 miles and the distance from the base to the apex is 90 miles. The delta of the Ganges and the Bramhaputra is 60,000 square miles. The whole of Northern India from the Punjab and Sind to Bengal and Assam consists of nothing but silt hundreds of feet deep, deposited by the Indus and the Ganges &c. It is estimated that the Ganges carries in a year 355,361,000 tons of solid matter. Cook calculated that if a fleet of 973 ships, each laden with 1000 tons of mud, were daily, to sail down the

Ganges to the sea, this fleet of vessels would just perform the average daily work performed by the waters of the Ganges.

Lakes.

Lakes are depressions filled with water, on the surface of the land. Lakes may be fresh-water lakes or salt-water lakes. Salt-lakes may be portions of sea cut off from the main body or they might be formed from the original sweet water lakes. The fresh water lakes have outlets while the salt lakes have none. When there is no outlet for a lake, every year salts are washed into it but are not removed since the waters of the lake go out by evaporation and not by flowing out. The concentration of salts increases year after year until at last there comes a stage when the salts are thrown down in layers. The Dead sea is an example of a lake where the concentration of salts is so much that no animal can live in it and layers of different salts have nearly filled up the lake.

There are practically very few lakes in India. The important lakes are in the extra-Peninsular area—such as Tibet and Kashmir. The sacred Mānasarovar and other lakes from which the Indus, the Sutlej and the Ganges start are in Tibet. The Sambhar is the most important of the salt-lakes of Rajputana. It has an area 90 square miles when full during the rainy season. Its depth is four feet then. During the dry season the lake gets dry with an encrustation of salt over it. The Lonar-lake of Berar is a deep hollow supposed to be a crater of an extinct volcano. The depression is 300 feet in depth and about a mile in diameter. It is surrounded by a rim of basalt. There is a shallow lake of saline water at the bottom.

The chief constituent of the water is sodium carbonate. The important functions which are performed by lakes are :—

(1) Lakes equalise temperatures of the surrounding localities.

(2) They regulate the drainage of the country in which they exist.

(3) They act as stores of sediments brought into them by the streams.

(4) Waters from different streams meet together in lakes and double decompositions take place between the various salts, some of which being insoluble are deposited.

(5) Along with the silt, remains of plants and animals are driven into lakes where they remain imbedded and after years, leave behind their casts or moulds as fossils. These fossils form a very valuable material in indicating the life of the period and the climatic and other conditions of the times in which they were deposited. These deposits, when dry, form the real pages of the history of the earth.

Oceanic waters.

Like the river waters the oceanic waters excavate, transport and deposit mineral material. The work is a combined action of wind waves, tides and currents. Huge waves of water attack the shores and the loosened material is carried away to long distances to be deposited or the material is lifted up by the waves and dashed against the very rocks from which the material is derived. With the rocky material the power of the waves is increased very much and they

are able to crush even very hard rocks. The fragments of rocks broken off are rounded by waves, worn down to sand and finally to silt like material which is deposited in layers to be turned into hard rock again. The disintegrated material carried into the oceanic waters extends from 50 to 200 miles from the coast land. The coarser materials are on the coast side and the finest particles furthest from the coast. Two hundred miles is practically the limit upto which the land sediment may be carried. Distant and deeper parts of the oceans have deposits from the decay of oceanic animals and plants. The action of sea-waters is restricted to coast lines only.

Terrestrial ice.

When the temperature of the water begins to fall the water contracts in volume and when it is 4°C its density is the greatest. If the temperature lowers still the water begins to expand and at 0°C when it changes from the liquid to the solid state, it suddenly increases in volume from 100 to 109. If the water is held in crevices or in a way where it cannot expand it exerts a pressure which is equal to 138 tons per square foot. This action due to lowering of the temperature of water shatters and breaks the rock to pieces, and squeezes rock particles against each other. In cold countries the snow which falls may show a protective action. When it falls and accumulates on young crops, it being a bad conductor, preserves warmth underneath and protects the plants from outside extreme cold. It may on the other hand prove to be destructive when it accumulates on hill slopes and comes down suddenly into the valleys destroying rocks, plants and animals over which it rolls.

In such mountains as the Alps and the Himalayas there are rivers of ice called *glaciers.* Snow heaps itself in huge piles on these mountains. The lowest portion of the snow, under the heavy pressure of the upper portions, throws out a sort of a tongue which moves slowly down the slope being fed and pushed from behind by the huge accumulated mass. It remains continuous till it comes down into warmer climates. Here it naturally melts and forms a current of ordinary water. Like an ordinary river a glacier has three-fold action—transporting, excavating and depositing. The material transported either on or in the glacier is called "*moraine*". The glaciers move but slowly, about 20 to 27 inches in 24 hours. The fastest found in Greenland move at the rate of 40 feet in a day. The material carried slowly by the glaciers grinds with great pressure against rocks over which they flow. Ultimately most of the material is dropped down where the glaciers melt into water. The average length of the Alpine glaciers is 3 to 5 miles. The Great Aletsch Glacier is 10 miles long and about 5900 feet broad. In India on the innermost ranges of the Himalayas enormous quantities of snow accumulate and feed a very large number of glaciers. Some of these glaciers are amongst the largest in the world and carry huge masses of debris in the form of moraines.

Glaciers.

At the poles there is perpetual snow even at sea level. The thickness of this is estimated at two or more miles therefore there are glaciers there many miles in length. From these glaciers huge masses of ice of enormous thickness and many square miles in extent, float away into the ocean and are

Ice bergs.

carried towards the equator. The portion of the iceberg which is seen above the water is only one-ninth part of the whole mass. The iceberg is also surrounded by thick fog and hence is many times difficult to spot. When the ice-berg enters warmer climate it melts and unloads itself of the rocky material brought with it, on the floor of the sea.

The total result of the combined action of the various forces like the rain, rivers, glaciers &c. in lowering the surface of the land by removal of material is known as *denudation.* Of the mineral substances received by the sea from the land, by far the larger portion is brought down by streams and a relatively small amount is washed off by the waves of the sea itself. It is the stream-borne part, therefore, which is very important in giving an indication of the amount of denudation. The real measure of denudation is the amount of material removed from the surface of the land and carried to the sea.

The general lowering down of the level of the land is shown by the following table from Geikie's Text-book of Geology.

Name of River.	Area of basin in sq. miles.	Annual discharge of sediment in cubic feet.	Foot of rock by which the drained area is lowered in one year.
Missiesippi	1,147,000	7,468,694,000	$\frac{1}{6000}$
Ganges	143,000	6,368,077,000	$\frac{1}{823}$
Rone	25,000	600,381,000	$\frac{1}{1528}$
Po	30,000	1,510,137,000	$\frac{1}{729}$

The Ganges removes one foot in 823 years. The average height of Asiatic continent is 1132 feet. The area worn down by the Ganges, will therefore be brought to sea-level in 930,000 years, by denudation if no upheaval or depression of the land takes place.

Action of vegetable kingdom.

Life as a dynamical agency acts through plants and animals. Plants have destructive, preservative and reproductive actions. The destructive action of the plants is seen in several ways. (1) Rocks in contact with vegetation are kept moist, especially when they are covered with moss and similar moisture loving plants. The moisture exerts solvent action and acts in various ways as already indicated in another place to disintegrate rocks. (2) By the decay of the vegetable material organic compounds are produced. These include, humic, ulmic and other acids. They have a great dissolving power on minerals and rocks and they also have a tendency to take up oxygen from the mineral matter and reduce it. The roots of the plants secrete a liquid which has an action like the acids mentioned above. (3) Some of the organisms of the soil such as bacteria, belong to the vegetable kingdom. These produce ammonia and nitric acid from organic matter and the nitric acid attacks mineral material. (4) Plants insert their roots into joints and crevices of the rocks and act as wedges in breaking rocks.

Among the preservative actions may be mentioned the following :—(1) Certain plants spring up on newly formed sand hills and protect them from being blown and scattered about by wind. (2) Formation of turf on land protects soil and loose material from being rapidly re-

moved by rain or wind. (3) Forest growth also protects soil especially on slopes by the binding action of roots.

The reproductive action of vegetation is very clearly seen in many places by the accumulation of the vegetable remains on and under the surface of the earth. (1) Huge masses of sea-weeds accumulate in layers. These weeds abstract mineral matter from the sea-water and when they decay the mineral matter helps the formation of rocks. (2) The man-grove growth binds and protects silt layers and islands of such deltas as those of the Ganges, and Irrawady. All these growths are slowly but continuously adding to the strata of the crust, though the amount may be small compared with the mechanically formed sediments, yet geologically it is of great importance. (3) The peat bogs of the several countries are good examples of reproductive action. Some of the peat areas extend over thousands of square miles and vary from 10 to 40 feet in thickness. These are specially developed in cold countries. In Ireland about one-seventh of the area is covered with bogs. Peat-bogs have treacherous surface and frequently men and animals that go there by mistake are engulfed. The peat possesses great anticeptic power and hence the engulfed material is well preserved in it. In India the formation of peat is confined to a few places. True peat is found on the Nilgiri mountain in a few peat bogs lying in depressions. Peat is found in the delta of the Ganges and also in the Kashmir valley and in the valley of Nepal. (4) The coal-fields found over the world are masses of mineralised vegetation of past ages. Under favourable conditions and through a long period of time, submerged peat, forest-growth &c. form coal deposits. Several coal fields have been discovered in India.

in recent years. The coal-fields of Bengal, Bihar, Orissa, Hyderabad state and Central Provinces are well known. The annual production is now nearly enough to supply the internal consumption. (5) Besides the carbonaceous deposits formed by plants siliceous or flinty accumulations take place in lakes and marshes through the growth and decay of microscopic organisms.

Action of animal kingdom.

Destructive actions of animals on rocks are shown by the fine material produced by ants, earthworms and such burrowing animals as the rats,rabbits and crayfish. Darwin showed that the common earth-worm is able to bring fine particles of earth from the lower portion of the soil to the surface. In fifteen years it may produce a layer of three inches of fine particles on the surface. The burrowing animals dig into the soil and subsoil and throw out material for disintegration by air and water. The burrows, tunnels and hollows produced by these animals help circulation of water and through its action the destruction of mineral matter.

Several instances can be given to show how animal life helps in building up the crust of the earth. Bones and other parts of large animals often get buried in mud and silt to be petrified. Protective secretions and coverings of small organisms form vast masses of rocky material. The shells of various sea animals accumulate and get mixed with silt forming thick beds. The vast chalky deposits on the floors of the ocean are calcareous shields of *foraminifera* organisms. Some of the sea muds are made of bodies of very tiny organisms. The coral islands which are so abundant in the oceans

are formed by the continuous growth of various species of corals. The deposits produced by the animals may be phosphatic, siliceous or calcareous.

Internal agencies.

The internal agencies are busy in wearing down higher portions and filling up hollows and thus tend to level down the surface. The internal agencies on the other hand have an opposite tendency of bringing up fresh materials and of elevating and depressing the earth's surface. The internal agencies are (1) The volcano, (2) The earthquake and (3) The crust movement.

Volcanoes.

Page and Lapworth describe a volcano as follows:—"A typical volcano is a conical mountain formed of the materials ejected to the surface through a fissure (or a crack) in the earthcrust from the heated regions below. The volcano has a pit shaped opening (the crater) near the summit, which communicates with the original fissure in the earth-crust by a central pipe or funnel (throat or vent), out of which are ejected clouds of steam, stony fragments, ashes, dust and lastly molten lava." When the volcano originates there are terrific explosions. They produce cracks in the earth-crust and from the. cracks come out different materials. The shattered fragments of the crust are blown up and they return to the ground in a scattered condition. The gaseous material is the first to come out from the interior of the earth. It is mostly steam. It goes up, gets condensed and falls down like rain. The solid fragmentary material consists of fine ash, angular or rounded cooled lava bits. The ash rises very high, and covers the sky. It is many times blown away

to distant places before it settles down. The fragmentary material is followed by molten lava (liquid rock) which pours over the lips of the crack and spreads in all directions. The lava may be very liquid and flow to great distances or it may be thick and accumulate in huge heaps round the mouth. Each ejected flow has to rise higher than the previous one and thus the volcanic mound goes on increasing in height. It acquires a conical shape. Sometimes the central pipe grows so high that the lava stream is not able to rise enough to flow over. The pipe or throat joining the upper mouth to the internal source gets chocked up. In such cases it may break through the sides and give rise to parasite volcanoes. These naturally destroy the conical form of the original volcano. The lava which comes in contact with the ground and cools more or less quickly has a tendency to be glassy, the portion above it cools slowly and has time to crystallise, while the uppermost portion which is exposed is full of holes on account of the escape of vapours or gases from the surface and is many times porous and light.

A volcano may be a small mound or a gigantic pile of lava with circumference of several miles. The Etna is 87 miles in circumference and 10,800 feet high. Sometimes the volcanic activity is not due to a small opening but is due to very long fissures throwing out lava material. In such cases the area covered by the lava is very extensive. The Deccan trap is supposed to be due to the lava thrown out from very long fissures and that is why it occupies a very large area. The volcanoes are generally found in lines along the coast lines where

the surface of the earth-crust is steep. A chain of volcanoes extends from the southernmost end of America, along the Andes, through California to Alaska. This then turns round and goes to Japan and Philippines and New Zealand &c forming a circle round the Pacific. Java, Sumatra &c form a line in the Indian ocean. The Atlantic chain starts from Iceland and goes down along the western coast of Africa. There is also one chain of volcanoes in the Mediterranean. Volcanoes may be active, dormant or extinct. Active volcanoes are at present exhibiting their activities. The dormant volcanoes are those which are not active to-day but which were active within historical knowledge and which may become active at any time. These volcanoes cannot be said to be dead or extinct. Vesuvius is a good example in this connection. It has been active and inactive alternately between 1500 and 1631 its activity had completely stopped and it was considered to be nearly dead but in 1631 a sudden erruption started the activity. Now and then it is active and not quite dormant. The extinct volcanoes are very old and have not shown any activity within human knowledge. The volcanic activities are not restricted to the surface of land but may take place even under sea water and on as extended a scale as on land.

Mud volcanoes.

Mud volcanoes throw out mud. They might be due to gases discharged or might be due to hot steam. The first type are not volcanoes in the proper sense of the term. They are conical hills formed by the accumulations of mud which mixed with gases is being thrown out from an orifice. The

second type of volcanoes are found in volcanic regions. Due to ebullition of steam, hot liquid mud is thrown out from these volcanoes.

Indian volcanoes.

There are no active volcanoes in India. There is a dormant volcano on the Barren Island in the Bay of Bengal to the east of the Andman Islands. The summit of the volcano is about 1000 feet high above the sea level. The part of the volcano seen above water is only a small part. The base of the cone is thousands of feet, below the surface of the sea. It was active in 1789 and in 1803 and since then it is dormant. There are three more dormant or extinct volcanoes in one line with the Barren island volcano. In Berar there is the Lonar lake which is supposed to be a crater of an extinct volcano. This has never shown any activity within human memory and all signs show that it is extinct. We have a very grand instance of the extinct long fissures. The whole of the Deccan trap seems to have been poured out from long fissures which are now extinct. The area occupied at present by the lava materials is very large—200,000 square miles and there are strong proofs to suppose that the area occupied must have been vaster still.

On the Arakan coast of Burma and also at some places on the Irrawady there are small mud-volcanoes. On Baluchistan side there exist a few mud-volcanoes. There is one mud-volcano near Karachi. The main continent of India has no volcano, active or dormant. Volcanic activity became extinct ages ago.

Earth-quakes.

Earth-quakes are rapid undulations of the earth-crust due either to the movement of the internal hot liquid or to a sudden slip or facture of earth-crust in a state of great strain. Sud-

den displacement is caused which gives rise to a series of waves which spread outwards in all directions and which, when they reach the surface, produce sensations called earth-quakes. Great earth-quakes are rare, but minor earth-quakes take place every now and then. They may be so small as to be recorded only by sensitive instruments. These minor earth-quakes may be as many as two per day. Earth-quakes may take place under the bed of an ocean. They then set the whole water in motion. The waters may move outwards from the land for a time exposing the sea-bed and then turn back towards the shores rushing over the coast far inland and bringing about terrible destruction. The origin of the earth-quake lies from five to thirty miles below the surface and is called the focus. The portion of the earth's surface which is vertically above the focus is called the *epicentre*. The district over which an earth-quake is perceptible to human beings without the aid of an instrument is its disturbed area. A great earth:quake never occurs alone. The most prominent shock is generally preceded and followed by minor shocks.

The shocks of the earth-quakes are sometimes felt over large areas. In 1819 a violent earth-quake occurred in Cutch, which seriously injured the town of Bhuj, and the shock of which was felt through Gujerat and even in the Deccan. The shocks from the earth-quake at intervals lasted for several days. A large extent of country was submerged to a depth of 12 to 15 feet while at the same time the Ullah bund, a mound 50 miles long and varying in breadth from 10 to 15 miles was raised several feet above the plain.

In the year 1897, on the 12th June a very disastrous earth-quake took place in India. It was between Shillong and Darjeeling. It was felt over a very wide area. The area of great intensity was 6000 square miles. It is recorded that the shock was felt over an area of 1,200,000 square miles. The Kangra valley earthquake which took place on the 4th of April 1905 was also one of the most violent earthquakes. The shock was felt all over northern India. Its effects were felt along two lines between Kangra and Kuly, and between Mussoorie and Dehra Dun.

Crust Movement. Although less conspicuous yet more effective is the upheaval and subsidence of large tracts. The crust-movement causes upheaval of land at some places and depression at others. This movement is due to the slow cooling of the internal material. The cooling causes slow sinking in volume and the solid crust in accommodating itself to the sinking volume moves up and down. The crust is thrown into folds or wrinkles. The movement being slow is noticed only after long periods. The effect is seen on rocks which get folds on the areas that have sunk or have been lifted up. The folding of rocks exerts a great pressure on the rocks and flattens their particles and crystals. The upheaval and subsidence are taking place even to-day. Thus the coast of Sweden is at present being elevated slowly at the rate of about four feet in a century, while a part of the Italian coast is sinking at the rate of about one inch annually. Although the Peninsular portion of India has been a stable land-mass for very long periods yet there are a few movements of land along the coast line. The most important

instance is the appreciable elevation of the Peninsula. Raised beaches are found along coast lines. The precipitous face of the Sahyadri is parallel to the sea coast and indicates that it must have been elevated. The Bombay island is a peculiar instance of both the elevation and the depression. Theodore Cook in his Manual of Geology says: "It is a curious fact that while much of the island of Bombay seems to have been recently elevated above the sea, a portion of the eastern side of the island appears to have been depressed. During the excavation for the docks at the eastern side of the island a considerable area was laid bare, on which the stumps of tree were discovered standing erect and evidently submerged as they had grown. These trees belonged apparently to the genus Acacia and evidently formed portion of a grove which grew on the spot, though the bases of the trees at the period of the discovery were 12 feet below low-water mark........" Similar instances of subsidence are found on the Tinnevelli coast and near Pondicherry. Rann of Cutch had in 1919 a subsidence of 12 to 15 feet. As a counter effect of this there was a simultaneous elevation of a plain into a mound several feet above the plane, called the "Ullah Bund". Within historical memory the Rann of Cutch was a gulf. It got silted up and was also elevated by internal lift and then it got depressed into a low lying tract.

Minerals.

Rock crystal.

Calcite.

Zeolite.

Agate.

Phosphatic Nodulc.

CHAPTER III.

IMPORTANT MINERALS.

Definition. A mineral is a homogeneous naturally occurring inorganic substance having theoretically a definite chemical compostition, and in most cases also a certain geometrical form. It may consist of one or more elements in definite chemical proportion. Although coal is a product of vegetable matter, by common usage it is regarded as a mineral substance.

Properties. Minerals have certain definite physical properties by which they are identified. These are:—

(1) Colour, (2) Lustre, (3) Degree of translucency (4) Hardness, (5) Streak, (6) Specific gravity and (7) Form.

(1) A mineral may be colourless, white, pink, black, green, yellow, brown, red, blue, violet &c.

(2) Lustre means the manner in which a substance reflects light.

There are different kinds of lustres.

(*a*) Metallic :—the ordinary lustre of metals as shown by copper, iron pyrites, graphite &c.

(*b*) Vitreous :—the lustre of glass. It is also called glassy. Rock-crystal, rock-salt calcspar have glassy lustre.

(*c*) Resinous :—the lustre of resin is shown by pitchstone, amber &c.

(*d*) Pearly :—Like a pearl showing play of colours. Selenite, mica &c., have this lustre.

(*e*) Silky :—Silk like lustre is shown by asbestos.

(*f*) Adamantine :—Resembling the lustre of the diamond.

There are also other types of lustre such as, waxy, opalescent, &c.

(3) Degree of translucency :—When the outlines of objects appear distinct through a mineral it is said to be transparent. When the outlines appear indistinct or only some light is seen through the mineral it is said to be translucent. When no light passes through a mineral it is said to be opaque.

(4) Hardness means the power of resisting abrasion or scratching. Moh's scale of hardness is taken as a standard and the order of hardness is as follows :— 1 Talc, 2 Gypsum, 3 Calcite, 4 Fluorspar, 5 Apatite, 6 Felspar, 7 Quartz, 8 Topaz, 9 Corundum and 10 Diamond.

The hardness of a mineral is determined by scratching it with minerals or substances of known hardness. Hardness may be tested with common substances also. The hardness of finger nail is 2·5, of copper 3, of glass 5·5 and that of sharp steel 6·5.

(5) Streak means the colour of the powder. The colour of the powder is sometimes different from the colour of the mineral crystal or mass.

(6) Specific gravity is the weight of a body compared with that of an equal volume of water. This is determined by any of the usual methods given in physics.

(7) Form :—Minerals assume various forms such as amorphous, crystalline, granular, platy, fibrous &c.

A crystal is a solid definite geometrical form which mineral matter assumes. Crystals are bounded by surfaces which are called faces. Intersection of two adjacent faces gives an edge, while the intersection of three or more faces gives a solid angle. The axes are mathematical straight lines intersecting each other in the interior of a crystal and connecting the centres of opposite flat faces of the crystal.

There are many varieties of crystal forms but they may be reduced to six types each one being distinguished from others by the number and position of its axes. These are as follows :—

1. Monometric (Isometric, cubical, regular) :—The axes of monometric crystals are all equal in length and intersect each other at right angles.

2. Dimetric (Tetragonal) :—The axes of dimetric crystals are at right angles to each other. Two of the axes are equal in length while the third is longer or shorter than the other two.

3. Trimetric (Rhombic, Orthorhombic) :—The three axes of trimetric crystals intersect at right angles but are all unequal in length.

4 Monoclinic:—Monoclinic crystals have all their axes unequal and one of them is oblique.

2 Triclinic:—Triclinic crystals have all the three axes unequal and oblique with each other.

6. Hexagonal:—Hexagonal crystals have got four axes three of which are equal while the fourth one which is at right angles to them may be shorter or longer. The three axes make an angle of 60^0 with each other.

Identification of minerals.

In identifying a mineral it is always safe to write down all the physical properties and then refer to the tables given; but many times it is easy to identify a sample by a process of elimination. From the colour of the mineral we are able to narrow down the sphere in search for the name. Next to colour hardness is the property which allows us to narrow down the sphere much further. If we take only those minerals which go to form important rocks we can proceed as under.

Colour:— The mineral is colourless. If the hardness of the mineral is 7 then it may be rock crystal. Further confirmed by the hexagonal form of the crystal and striations on the side of the crystal.

Hardness 5 with many times needle shaped crystals indicates zeolite.

Hardness 3, heavy to feel may be byrites; effervesence with hydrochloric acid shows calcite.

Hardness 2 or less, crystals or thick plates show gypsum; flexible plates indicate mica.

Colour:—white.

Hardness 7 indicates milk quartz.

Hardness 6 shows felspar if it has flat faces, opal if it has opalescent lustre.

Hardness 3, heavy to feel is byrites; quick efferve-scence with hydrochloric acid is calcite; slow efferve-scence indicates dolomite.

Hardness 2, fibrous, with silky lustre is asbestos.

Colour:—Pink.

Hardness 7, crystalline is rose quartz.

Hardness 6, flat face crystal is felspar.

Hardness 5, is zeolite.

Colour:—Black.

Hardness 6, attracted by a magnet is magnetite. Varying hardness, black streak, not attracted by a magnet is manganese ore. Greenish white streak is hornblende.

Hardness 2, flexible plates is biotite.

Hardness less than 2 with metallic lustre, soapy feel is graphite.

Colour :—Green.

Hardness 7 may be prase, with red spots it is bloop stone.

Hardness 6 with yellowish green colour is augite.

Hardness 5 with large crystals may be apophylite!

Hardness 3, yellowish green, needle like crystals is actinolite.

Hardness 2, deep green plates with pearly lustre, with smooth feel is chlorite; with earthy lustre glauconite. light green with soapy feel is talc.

Colour :—Yellow.

Hardness 6, brass yellow in cubes is iron pyrites.

Hardness 3 to 4, peacock colour, greenish black streak is copper pyrites.

Hardness 2, with resinous lustre may be sulphur.

Colour :—Brown.

Hardness 7 may be jasper; with opalascent lustre and hardness a little less than six may be opal.

Hardness about 5 with cherry red streak is hæmatite, with yellowish streak is limonite.

Colour :—Red.

Hardness 7, quite opaque may be jasper; green and red may be blood stone; bright red transparent or translucent is carnelian.

Colour :—Blue.

Hardness 7 may be flint.

Colour :—Violet.

Hardness 7, crystalline may be amethyst.

It has been estimated that the crust of the earth is made of the chief minerals in the following proportions,—Felspar 48 percent, Quartz 35 percent, Mica 8 percent, Talc 5 percent, Carbonates of Lime and Magnesia 1 percent, Hornblende 1 percent, and others 2 percent.

Minerals are classified as elements, oxides, silicates, carbonates, sulphates, sulphides, phosphates, chlorides &c.

Name of mineral.	Composition.	Colour.	Lustre.	Translucency.
ELEMENTS.				
1 Graphite	Carbon	Dark gray to black.	Metallic	Opaque
2 Diamond	Carbon	Colourless, frequently various tints	Adamantine	Transparent to opaque
3 Sulphur	Sulphur	Shades of yellow.	Resinous	Translucent
OXIDES				
4 Quartiz or silica	Silicon dioxide			

Four groups of this mineral consist of (1) Rock crystals and its varieties (2) Chalcedony and its varieties. (3) Jasper and (4) Opal.

(1) Rock crystal with hexagonal varieties				
(a) Rock crystal.		Colourless		
(b) Amethyst		Purple, violet		
(c) Rose quartz		Rose		
(d) Milk quartz		White		
(2) Chalcedony	Translucent, Semicrystalline			

Hardness	Streak	Sp. Gr.	Form	Locality
1 to 2	Dark gray	2	Commonly foliated, granular	Vizgapatam, Chhatisgarh. Coorge, Godavari district.
10	None	3·5	Octahedral	Panna, Bhaganpalli &c.
1 to 2	White or yellowish	2	Crystals or massive	Barren Islands, Baluchistan &c.
7		2·5 to 2·8		
				Tanjore, Godavari beds, Deccan Trap. Jabbulpore Tanjore

Name of mineral	Composition	Colour	Lustre	Translucency
(a) Carnelian		Pale to deep-red.		
(b) Prase		Dull green		
(c) Agate		Layers of two or more different colours	Banded	
(d) Moss agate				Translucent with moss like appearance inside
(e) Flint		Blue, smoky or brown.		
(f) Bloodstone or Heliotrope		Showing small spots of bloodred jasper		
(g) Chert impure flint.				Opaque
3 Jasper		Dull red, brown, yellow &c.		Opaque
4 Opal compact amorphous variety		All colours.	Greasy vitreous	
5 Oxides of Iron				Opaque

Hardness	Streak	Sp. Gr.	Form	Locality
				Cambay.
				Nilgiri
				Rajmahal Hills.
				Morvistate and beds of Godavari Krishna and Bhima.
				Cuddapah Bagalkot, Jubbalpur &c.
5·5 to 6·5	White	2·2		Deccan Trap.

Name of mineral	Composition	Colour	Lustre	Translucency
(1) Haematite	F_2O_3	Steel gray, black, red	Metallic earthy	Opaque
(2) Limonite	$2Fe_2O_3$ $3H_2O$	Yellowish brown	Sub-metallic, dull,	Opaque
(2) Magnetite	Fe_3O_4	Black	Metallic	Opaque
6 Manganese Oxide or Pyrolusite	MnO_2	Black	Metallic to earthy	Opaque
7 Aluminium Oxide Corundum	Al_2O_3	All Colours	Vitreous	Transparent to translucent.
Silicates				
8 Felspars			Vitreous	Translucent to opaque
Varietiesof Felspars:—				
(1) Orthoclase	Potassium aluminium silicate	Flesh red or white		
Plagioclase group				
(2) Albite, oligoclase and labradorite	Sodium aluminium. silicate	White		

Hardness	Streak	Sp. Gr.	Form	Locality
5·5 to 6·5	Bright red to reddish brown	4·5 to 5·3	Crystalline granular or massive	Jubbalpore, Gwalior, Peninsular India
5 to 5·5	Yellowish brown	3·6 to 4	Concretionary, massive	Large deposits in Peninsular India,
5·5 to 6·5	,,	4·9 to 5·2		Deccan trap, Lower Sind
2 to 5·5	Black	4·8 to 5	Crystalline granular or massive	Kaladgi, Bellary, Jubbalpore &c.
9	White	3·9 to 4·16	Crystalline	Salem Dist. Mysore, Rewa.
6	White	2·5	Orthoclase group monoclinic crystals plagioclase group triclinic crystals	Granite, Gneiss and trap area

Name of mineral	Composition	Colour	Lustre	Translucency
(3) Anorthite	Calcium aluminium silicate	Gray or reddish		
9 Zeolites		White, sometimes reddish pinkish or ee n	Vitreous, pearly	Transparent to opaque
Varieties of Zeolites				
(1) Stilbite	Calcium sodium aluminium silicate			
(2) *Heulandite*	*Calcium* aluminium silicate			
(3) Apophylite	Potassium calcium silicate			
10 Micas			Vitreous, pearly	Transparent
Varieties of Micas				
(1) Muscovite	Potassium aluminium silicate	Colourless to light tints		

Hardness	Streak	Sp. Gr.	From	Locality
4 to 5·5		2·3 to 2·4		Trap area
			Monoclinic crystals, sheaf like bunches or radiated.	
			Monoclinic crystals	
			Prismatic, cubical or tetragonal crystals	
2 to 3	White	2·7 to 3·1	Scales or plates.	Mica schists of the peninsula. Nellore dist. of Madras and Gaya, Hazaribag of Bengal.

Name of the mineral	Composition	Colour	Lustre	Translucency
(2) Biotite	Potassium msgnesium iron aluminium silicate	Black dark brown, rarely green		
11 Amphibole or Hornblende	Sodium Potassium calcium magnesium manganese iron aluminium silicate	Greenish to black	Vitreous to silky	Translucent to opaque
Varieties (1) actinolite		Green		Transparent long crystals
(2) amphibole occurring in long, flexible silky fibres is known as asbestos				
12 Augite	Calcium, Magnesium aluminium iron silicate	Light to dark green	Vitreous	Translucent to opaque
13 Chlorite	Silicate of aluminium magnesium and oxide of iron	Green with various shades	pearly	Translucent
14 Talc	magneciam silicate	White, light green or red	Waxy to pearly	Translucent

Hardness	Streak	Sp. Gr.	Form	Locality
5 to 6	White to greenish	2·9 to 3·4		In the Gneissic and schistose rocks
6 to 7	White to greenish	3·3 to 3·5	Crystalline, granular or massive	Merwar, Rajputana, in Garhwal, in the United Provinces and in Mysore State.
1·5	Greenish white	2·6 to 2·8	In plates with greasy feel	Trap and gneissic a rea
1	White	2·5 to 2·8	Foliated or massive has soapy feel	In several altered and metamorphic rocks

Name of mineral	Composition	Colour	Lustre	Translucency
15 Glauconite	Potassium, calcium, magnesium aluminium iron silicate	Green	Vitrious to earthy	Opaque
Carbonatea				
16 Calcite	Calcium carbonate	Colourless, white or with shades	Vitreous to earthy	Transparent
Varieties. (1) Iceland spar		Colourless and flawless		
(2) Satin spar is fine fibrous with silky lustre (3) Dog-tooth spar is acutely pointed & often rounded				
17 Dolomite	Double carbonate of calcium and magnesium	White or with shades	Vitreous to pearly or earthy	Translucent
Sulphates				
18 gypsum	Calcium sulphate	White with various tinges when impure	Pear.y, silky, vitreous	Transparent
Varieties (1) Selenite transparent crystals or plates				

Hardness	Streak	Sp. Gr.	Form	Locality
2	Greenish	2·2 to 2·4	Crystalline or granular	Found in trap, many times as a very thin coating
3	White	2·6	Crystalline or grannlar	Almost every where
3·5 to 4	White	2·8	Granular or massive or crystalline	
2	White	2·3	Monoclinic crystals, granular or massive	Sind, Trap area Cutch Jodhapur &c.

Name of mineral	Composition	Colour	Lustre	Translucency
(2) Satin-spar with silky lustre				
(3) Alabaster white, finely granular				
19 Barytes	*Barium* sulphate	White	Vitreous	Transparent to opaque
Sulphides				
20 Iron pyrites	Iron sulphide	Pale to brass yellow	Metallic	Opaque
2I Copper pyrites	Copper sulphide	Bright, greenish yellow	Metallic	Opaque
Phosphates				
22 Apatite	Calcium phosphate *with some* chloride & fluoride. Phosphate rock found massive has 2 to 5 hardness	Various colours	Vitreous, resinous or dull	Translucent to opaque

Hardness	Streak	Sp. Gr.	Form	Locality
	White	4·3 to 5·6	Crystalline	Salem, Jubbal pore
6 to 6·5	Greenish black	5	Isometric cryastals, granular or massive	Various parts of India. Near Kalabagh on the Indus, it is abundant, in shales.
3·5 to 4	Black		Crystalline or massive	
5	White	3	Hexagonal crystals or massive	
				Trichinopally

CHAPTER IV.

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IMPORTANT ROCKS.

A rock may be defined as a mass of matter (generally inorganic) composed of one or more minerals, having for the most part a variable chemical composition, with no necessarily symmetrical external form, and ranging in cohesion from loose or feebly aggregated debris up to the most solid stone. Loose sand, coal, limestone, trap, though unlike each other are all rocks.

Rocks are classified into three main classes:—

(1) Aqueous, (2) Igneous and (3) Metamorphic.

1. Aqueous rocks are formed by the action of water. They are also called sedimentary because they are made up of sediments and are called stratified because they are in strata or layers.

2. Igneous rocks are formed by the action of heat. They are also called crystalline because they are made of crystals and are called massive because they are not in layers but in masses.

3. Metamorphic, rocks are formed by change either in the aqueous or in the igneous rocks.

The following are a few important terms used in describing rocks:—

1. (a) Primary mineral is a mineral which is an essential constituent of the rock. It is formed with the rock.

(b) Secondary mineral is that mineral which is deposited on or in the rock after its formation. A mineral may be both primary and secondary in the same rock. Granite rock is made up of felspar, mica and quartz and quartz is therefore a primary mineral in granite because without it the rock will not be a granite. After the formation of granite quartz may be deposited on it. This deposited quartz will be a secondary mineral.

2. Prophyritic rock is composed of a finely crystalline ground mass in which larger crystals of felspar &c. are dispersed.

3. Foliated rock consists of minerals that have crystals approximately parallel, lenticular, and with usually wavy layers or folia.

4. Concretionary rock consists of mineral matter collected round some centre so as to form irregularly rounded mass. Concretionary trap exfoliates like peels of an onion, when it begins to decompose.

5. Vesicular or cellular :—In many igneous rocks the expansion of internal steam, while the mass was still in a molten condition has produced vesicles or cells. Such rocks are called vesicular.

6. Amygdaloidal :—When vesicles of a rock are filled with mineral matter (amygdales=almond) they are called amygdaloidal.

7. Dendritic rock is one which has dendrites. Dendrites are deposits of some metallic oxide of iron or manganese formed on minerals or rocks. Many times these dendrites present a strong resemblance to vegetable forms as to be readily mistaken for fossil plants.

8. Beds of aqueous rocks are called strata. Each stratum may be made up of subordinate layers called laminae.

9. When the beds are tilted they become inclined. The amount of inclination or the angle which the inclined rocks make with the horizontal plane is called the '*dip*'. This can be measured by a clinometer.

10. The line of direction followed by an inclined bed in crossing the surface of the country is known as its '*strike*'.

11. *Out crop* is the actual edge of the inclined stratum at the surface of the ground.

12. Due to the crust-movement the rocks get a wavy or an undulating form. The portion which is pushed up is called an '*arch*' and the portion which is depressed is called a '*trough*'. Each such wave formed of an arch with a companion trough is known as a '*Geological fold*'.

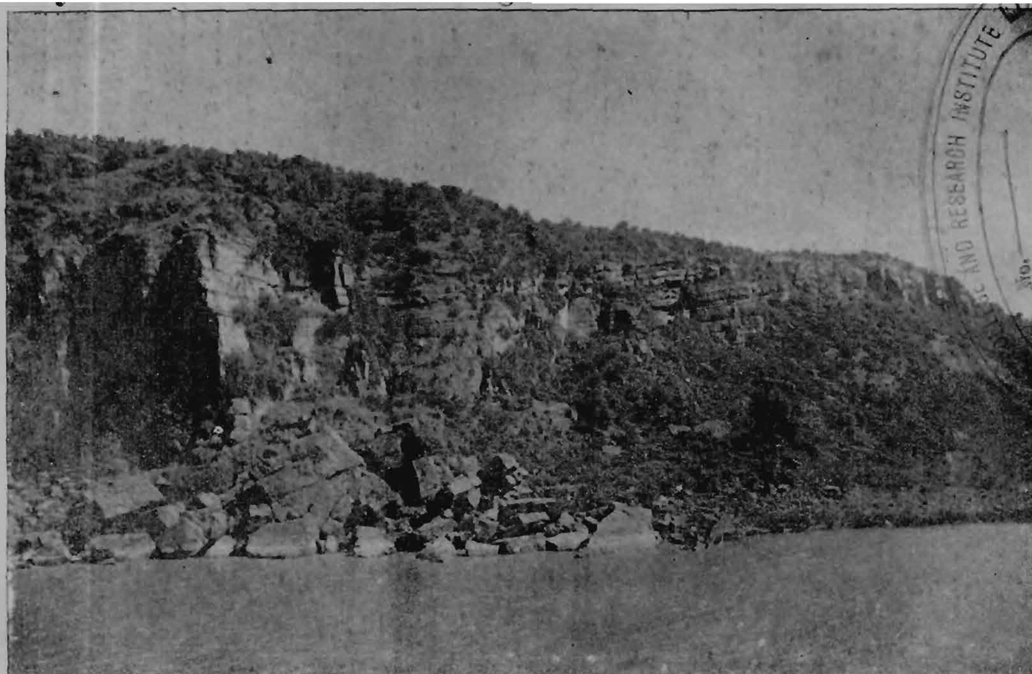
13. '*Vein*' of an igneous rock means a narrow band or string of igneous rock which fills up an irregular and narrow fissure or a crack.

14. A *dyke* is a wall-like mass of igneous rock filling up a vertical fissure with parallel walls.

AQUEOUS ROCKS.

The binding material in the consolidated rock of aqueous origin is formed from one or more of the following :— (a) silica (b) lime and (c) iron oxide.

Aqueous rocks are divided into (A) arenaceous or sandy, (B) argillaceous or clayey (C) Calcareous and (D) Carbonaceous.



Sandstone layers, forming a shallow trough and an arch on the left side of the gorge of the Ghataprabha Falls.

(A) Arenaceous loose rocks :—

1. Shingle is composed of large rounded pebbles.
2. Gravel is a mixture of angular and water worn fragments.

Arenaceous consolidated rocks :—

1. Conglomerate is composed of water worn pebbles. Fragments may be of any rock.
2. Breccia is composed of angular fragments.
3. Sandstone is composed of consolidated sand.
4. Grit is composed of sharp and angular sand.

(B) Argillaceous loose rocks .—

1. Clay, mud &c. are sediments.
2. Kaolin or china clay is produced by the decomposition of felspars.
3. Pipe clay is clay free from iron.
4. Fire clay is clay free from lime and alkalies.
5. Fuller's earth is greenish earth not plastic and consists of aluminium silicate with some magnesia,.
6. Laterite is a cellular, reddish ferruginous clay formed in tropical countries as the result of sub-aerial decomposition of basalt, granite &c. It acquires hardness on exposure.

Argillaceous consolidated rocks are :—

1. Mudstone is of greater hardness than any form of clay.
2. Shale is a somewhat hardened argillaceous rock which is stratified.

(C) Calcareous rocks consist mostly of calcium carbonate and are designated by the general term 'lime-

stone'. Other names are used only to indicate formation such as chalk, stalactite &c. A limestone may contain magnesium carbonate along with calcium carbonate when it is called dolomite or magnesian limestone.

(D) Carbonaceous rocks include all the varieties of coal.

IGNEOUS ROCKS.

Igneous rocks may be classified according to the percentage of silicic acid (silica).

(A) Acid rocks contain silica above 65 percent. The characteristic minerals of these rocks are orthoclase felspar, mica and free quartz. The mica may sometimes be replaced by hornblende. The important rocks are :—

1. Granite, an aggregate of crystals of the above minerals. Giant granite contains large crystals, micro-granite contains fine crystals. Granite may sometimes be porphyritic.

2. Rhyolite has fine grained minerals with flow structure like that of furnace slag.

3. Obsidian is volcanic glass having the above minerals.

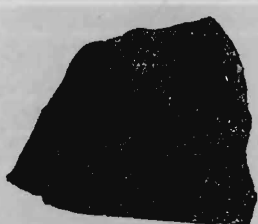
4. Pitchstone has the above minerals not crystallised and has resinous lustre.

(B) Sub-acid rocks contain silica from 60 to 65 percent having orthoclase and hornblende as the characteristic minerals. Hornblende may sometimes be replaced by mica.

1. Syenite is distinctly crystalline.

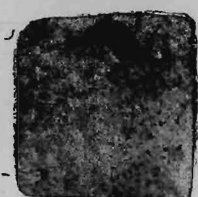
2. Trachyte has a rough and harsh feel on fractured surface, contains minute felspar crystals.

Rocks.



Granite.

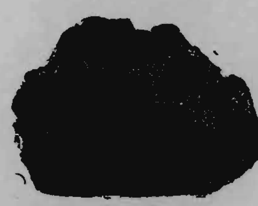
Gneiss.



Marble.

Schist.

Concretionary Trap.



Laterite.

(C) Sub-basic rocks contain 55 to 60 percent silica with plagioclase felspar and hornblende as characteristic minerals.

1. Diorite is a typical rock of this class.

(D) Basic rocks contain silica from 45 to 55 percent. The characteristic minerals of this class are plagioclase felspar, pyroxene and magnetite with sometimes olivine.

1. Granitoid or large grained variety is gabbro. Rocks with small crystals include the following :—

2. Dolerite when the crystalline matrix is visible

3. Basalt has microcrystals and is compact.

The various varieties of trap will come under basic rocks with small crystals. Dolerite and basalt both can be included under the term trap. Some of the varieties of trap are :—Vesicular, amygdaloidal, porphyritic concretionary &c.

ALTERED AND METAMORPHIC ROCKS.

Both aqueous and igneous rocks may undergo alteration after their original formation. The alteration may be produced by (1) water (hydro-metamorphism). (2) Heat (thermo-metamorphism) or (2) Pressure (dynamo-metamorphism).

(1) Sandstone may become consolidated by infiltering of some cementing material. The hardened sand stone is called quartzite.

(2) Great masses of igneous material in a molten state may come in contact with the original rocks and may change them into fused or crystalline rocks. Sand

stone may become a quartzite, or a limestone may become a crystalline marble.

(3) Irresistible pressure is produced by the crust movement and the rocks get pressed and flattened. Shale may in this way be changed into a hardened slate.

The pressure of the crust movement or the pressure produced by the molten material that may inject itself into any original rock has one great effect on the crystalline rocks. Their crystals are flattened. These flattened crystals become folia (leaves), thick in the middle and thin at the edges. The edges overlap each other and hence rocks whose crystalline material is in a flattened or foliated state are known as foliated rocks.

There are two groups of foliated rocks. In one group the crystals are only slightly flattened and are not separable into folia. A rock of this type is called a gneiss. The term 'gneiss' refers to the foliated condition and not to the composition of the rock and hence a gneiss with granite minerals will be granite gneiss and one with diorite minerals will be a diorite gneiss and so on.

In the other group of the foliated rocks the crystals are very much flattened and the foila are easily separable. The rocks of this type are called schists. 'Schist' is a term which refers to the foliated condition of the rocks. A schist may according to the most prominent mineral or rock forming it, be called a talc-schist, quartz-schist or diorite schist &c.

In identifying rocks the work will be easier if some system as given below is followed—

Identification of rocks

1. A fresh fracture shows the rock to be close-grained, dull, with no distinct structure and is—

Haematitic quartzites nearly vertical in a Quarry near Gadag, (Dharwar District.)

(*a*) Soft, crumbling, emits earthy smell, does not effervesce with acid, it may be of any colour as red, yellow, white, brown &c—then it may be shale or fire clay. If a little bit hard it may be clay slate.

(*b*) White or yellowish, brisk effervescence with acid, it may be some variety of lime stone.

(*c*) With feeble effervescence, which is vigorous on powdered material—may be dolomite.

(*d*) Brown to dull black in colour, slowly dissolved by acid—may be some iron ore.

(*e*) Black with weathered crust yellow or brown —may be trap.

2. A fresh fracture shows the rock to be fragmental.

According to the size & shape of the fragments the rock is classified as conglomerate, breccia, grit or sandstone.

The cementing material may be lime, some iron oxide or silica. If a drop of acid produces effervescence it indicates the presence of lime. If the grains show reddish, brownish &c. colour it is an indication of the presence of iron oxide. When the matrix is exceedingly hard, white in colour it is probably siliceous.

3. A fresh fracture is crystalline.

If the component crystals are sufficiently large there is no difficulty in identifying them. If the rock has very minute crystals it should be tested for its hardness.

(*a*) If it is easily scratched with knife.

(1) Effervescence with acid—limestone.

(2) Effervescence only on powder—dolomite,

(3) No effervescence—gypsum.

(*b*) If the rock is not easily scratched it is some silicate. If it contains magnetite it is some variety of trap such as dolerite, basalt &c. If it contains quartz crystals it is granite rhyolite etc.

4. A fresh fracture shows foliated structure.

CHAPTER V.

ROCK SYSTEMS OF INDIA

For geological purposes India may conveniently be divided into three parts :—(1) the great Indo-Gangetic alluvial plain including the Punjab, Sind, Upper India and Bengal, (2) the triangular portion of the peninsula lying to the south and (3) the extra–peninsular area consisting of the hilly countries west, north and east of the Indo-Gangetic plain.

The Indo-Gangetic plain consists of the alluvial material brought down by such rivers as the Indus, the Ganges &c. The peninsula has been a dry land for ages and has undergone but little change in recent years. The extra–peninsular area has undergone great compression and disturbance.

Historically rocks are classified according to the age of their formations. In India we have the following systems. (The formations of the extra-peninsular area are not included here.)

Aryan	10 Recent Alluvium 9 Older Alluvium 8 Laterite 7 Tertiary 6 Deccan Trap 5 Coal bearing Strata found in Central Provinces, Bengal &c.

Dravidian Group	Absent in the Peninsula
Puran Group	4 Vindhyan 3 Cuddapah
Oldest	2 Dharwar or transition 1 Crystalline gneisses and granites.

Gneisses.

1. The oldest rocks in India are the granites and the gneisses which occupy a larger area in the Peninsula than all the other rocks put together.

These are found occupying a very large portion of the Madras presidency. In the Bombay presidency they are found in Belgaum, Dharwar, North Kanara and Ratnagiri districts and in some parts of the Baroda state, the Panch Mahals and the Aravali hills of Rajputana. These rocks are also found in Orissa, Central Provinces and Chota Nagpur. These rocks consist of felspar, quartz, mica or hornblende. Secondary minerals found in these rocks are chlorite, epidote, kaolin and sometimes actinolite, corundum and apatite &c.

The granites form excellent building stones. They take very good polish. Decomposition of felspar in the granites and the gneisses yields kaolin.

Dharwar system.

2. Dharwar system is also called the transition system. As found at present in the Bombay presidency and the Mysore state, it occupies a series of long bands of highly disturbed beds folded and faulted into the gneiss. The bands extend from the southern limit of the Deccan trap to the Cauvery valley. Besides these larger bands there are some

outliers like the gold-fields of Kolar. The rocks of the Dharwar system are hornblende and chlorite schists, phyllites (clay schists, with contemporaneous trap, diorite, banded jasper, schistose slates and haematitic quartzites consisting of alternating layers of haematite and quartzite. The Dharwar system is important because this is the system which contains gold in quartz reefs in Southern India. This system is also met with in Central Provinces, (Jubbalpore &c.) Gwalior, Bijwara and Aravali region.

Cuddapah and Vyndhyan systems.

3. Next to the Dhawar system in age is the Cuddapah system and over it the Vyndhyan system. These two systems differ but very slightly from each other. The Vyndhyan is newer than the Cuddapah.

Cuddapah system gets its name from the town Cuddapah in the Madras presidency where the rocks of this system are found occupying a large crescent shaped area. In the Bombay Deccan the rocks of the Cuddapah system are found in a basin called after the Kaladgi town. From the Krishna below its confluence with the Ghataprabha, the Kaladgi rocks stretch continuously westward for more than 100 miles. The rocks of the Vyndhyan system are found to a certain extent over the Cuddapah in the Madras presidency but they are found occupying large areas in Bundelkhand, Malwa, between Agra and Gwalior &c.

The rocks of this system are shales, sandstones, conglomerates, breccias, limestones, slates &c. The Vindhyan system contains the diamond bearing strata of India.

The sandstones form excellent building stones. Shahabad and Cuddapah limestones are used for flagging.

Gondwana system.

4. Above the Vindhyan is the coal bearing system of India known as the Gondwana system. The rocks of this system are found in Central Provinces, Bengal, Eastern coast &c. Small exposures are found in Kathiawar, Cutch and Western Rajputana. The rocks of the Gondwana system are shales and sandstones full of coal layers. The soils of this formation are poor.

Trap.

5. At the end of the Gondwana period a great revolution in the physical geography took place. The Gondwana land was broken up. On the northern side, the rise of the Hymalayan range took place while in the Peninsula igneous action on a tremendous scale poured out lava material over a large area. The present trap area is a remnant of that igneous action. It is known as the Deccan trap area. At present the trap occupies an area of over 200,000 square miles covering Cutch, Kathiwar, part of Gujarat, Deccan, Central India, western parts of Central Provinces and the Hydrabad state. The trap consists of lava eruptions coming out from fissures and cracks in the crust of the earth. There were three distinct periods in which the lava material was thrown out. Between every two periods there was enough time for the lava to cool and allow the formation of rivers and lakes and allow plants and animals to live. These plants and animals are found as fossils in rocks known as intertrappean because they are aqueous rocks found between trap layers. Individual lava layers vary in thickness from

10 to 25 feet and sometimes to 50 feet. Total thickness of trap on the coast of Bombay is estimated at 10,000 feet. The word trap comes from a Swedish word which means steps. The trap hills which consist of horizontal lava layers present a step like appearance. Between the trap layers sometimes red coloured earthy material is met with. It is known as red bole. The colour of the trap rock varies very much—from black colour to gray light red or light green. The texture also varies from exceedingly fine grained basalt to coarsely crystalline dolerite. Vesicular trap is not uncommon. The vesicles are many times found filled with such minerals as calcite quartz, zeolites &c. and the rock is then called amygdaloidal. The primary minerals of trap are the felspar, pyroxene and magnetite. The secondary minerals found in trap are:—The different varieties of quartz, zeolites, felspar, calcite and glauconite. Between the layers of traps sometimes fossiliferous beds are met with. These are known as intertrappean beds. The trap yields good and strong building stones and material for road-metal.

Tertiary system.

6. Newer than the trap and in some places overlying it are rocks found in different parts of the Bombay presidency. They are called Tertiary. In the Surat and Broach districs ferruginous clay, sandstones and limestones are found. Some of the limestones contain fossils of the nummulite types. In Kathiawar there are Dwarka beds consisting of clays and sandy limestones. Similar rocks are met with in Cutch also. In Sind Tertiary rocks are met with in the hills of Kirthar, Laki, Suleiman &c. The rocks are of aqueous origin consisting of shales, sandstones and limestones many of which are fossiliferous.

7. The laterite is newer than the tertiary rocks.

Laterite. Laterite is an argillaceous or clayey rock with a large number of vesicles or holes. It is soft when freshly dug out but hardens on exposure and is therefore used for building. It is composed of hydrated oxides of alumina and iron and sometimes contains oxide of manganese also. It is red, yellowish red or mottled with white spots. The colour is due to iron. Although the laterite is generally found distributed on the tops of trap hills in the Deccan, Central India and Central Provinces, yet it is observed on other rocks and formations also. The laterite is of two types the high level laterite found on situations above 2000 feet and the low level laterite found on coastal areas. The low level laterite is of detrital origin and is formed of the products of disintegration of the high level laterite.

There is a good deal of dispute with regard to the formation of the laterite. It seems to be a subaerial decomposition *in situ* of various rocks under a warm and humid climate. Under these conditions the silicates decompose, the silica is washed away and the hydrated oxides of alumina and iron are left behind. This decomposition is supposed to be helped by certain organisms.

8. The Indo-Gangetic alluvium extends over 300,000 square miles and includes Sind, Rajaputana, the Punjab, the United Provinces, Behar, Bengal and part of Aassam. It seems that originally there was a depression at the foot of the Himalayas connected with the upheaval of those mountains. This depression is now filled with the waste of the high lands. Thickness of this material is over

Indo-Gangetic Alluvimm

1000 feet and consists of silt and full of lime. The material is brought down by the Indus, the Ganges and the Bramhaputra &c. There are evidences to show that these rivers have changed their courses from time to time. The Indus for instance, flowed once into the Gulf of Cambay, then in the Rann of cutch and now in its present place.

9. Among the recent alluvial deposits are those found on the banks and at the mouths of the rivers Narbada, Tapi, Godavari, Krishna, Cawery &c. They include the black cotton soils of Gujerat and the Deccan.

CHAPTER VI.

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FORMATION OF SOILS.

Definition of soil.

Soil is the layer of more or less disintegrated rock, which covers a large portion of the surface of the earth and which is fitted, under suitable climatic conditions to support the growth of plants. In addition to the mineral constituents which usually form the largest portion, all soils contain some quantity of organic matter resulting from decay of previous vegetable growth. Soil also contains varying quantities of water, gases and living organisms. The soil rests on the sub-soil.

Subsoil.

The subsoil is found immediately below the soil and between it and the layer of unweathered rock. The subsoil is seldom stirred by tillage and hence is generally more compact than the soil and is often of a different colour. Its component particles are coarser than those which form the soil. The subsoil is formed ordinarily from the disintegration of the rock on which the subsoil stands. The soil is a further step in the disintegration. Soils and subsoils which are formed by washing of the disintegrated rocks may not rest on the rocks from which they are derived. The inorganic material of the subsoil is in a less available form to the plants than that found in the soil. The subsoil contains a smaller quantity of organic matter and a smaller number of organisms than the soil. The water and gases may be present in any proportion. In every respect the subsoil is between the soil and the rock.

Rock.

The rock is comparatively a hard and undisintegrated mineral matter. The mineral matter in the rock is mostly in an unavailable form to the plants. The rock contains but a negligible quantity of organic matter (except in peats and coal fields) and living organisms.

Soil-forming minerals.

As all soils are derived from rocks and all the rocks are composed of minerals we must have knowledge of the decomposition of minerals and rocks by the various decomposing agencies to help in judging the probable composition and character of a soil. Although the number of minerals is very large, yet those minerals that are prominently concerned in the formation of soils form but a small group. The soil forming minerals are :—Quartz and its varieties, felspars, hornblende and augite, micas, zeotites, oxides of iron, calcite, dolomite and gypsum.

Rate of decomposition.

The rate of decomposition of the minerals and rocks will depend on climatic conditions. In cold countries the water as a solvent will be less active than in warmer climates. On the other hand in cold countries expansion and contraction of particles produced by freezing and thawing break down the rock mechanically. In arid regions similar disintegration may be produced by extreme variations in temperature. In humid climates water and vegetable matter may help decomposition of minerals and rocks.

Quartz.

Quartz and its varieties—Quartz is silicon dioxide either crystalline or amorphous. Its mechanical disintegration is more in

advance than its chemical distintegration. Mechanically it is reduced to powder forming the sand which constitutes a large portion of soil. Sillica though in the ordinary sense is insoluble yet it is not altogether insoluble. Even at ordinary temperature it dissolves slightly in water. At high temperature and pressure underground water is able to dissolve it in an appreciable quantity. Water containing carbon dioxide dissolves silica especially by breaking the silicates. Fine silica deposited on the stems of grasses and such crops as rice is all from the soluble silica absorbed by plants and then deposited on stems.

Felspars

Felspars are silicates of aluminium and of one or more of the following :—sodium, potassium, and calcium. Felspars being less hard than quartz are ground down more easily than quartz by the mechanical agents. It is turned into a fine powder. Chemically also it is attacked more easily than quartz. Water containing carbon dioxide attacks felspars and decomposes it. The products of the decomposition of felspars are free silica forming sand, hydrated silicate of aluminium called kaolin which forms the clay in the soil and carbonates of such metals as sodium, potassium or calcium as may be present in the original mineral. The felspars thus yield a large number of soil constituents.

Hornblende.

Hornblende or amphibole and pyroxene or augite differ but very little in their composition from each other. They are silicates of alumina, lime, magnesia and iron ; manganese and alkali metals also are generally present. Hornblende although

of the same hardness as felspar yet decomposes more quickly than the felspar because in the first place it has an easy cleavage and therefore cracks readily and secondly because it contains ferrous silicate, it is attacked quickly by the atmospheric oxygen. Water containing carbon dioxide and oxygen attacks the mineral in various ways producing ultimately a little free silica, clay, carbonates of lime and magnesia, oxides of iron and also perhaps small quantities of carbonates of soda or potash.

Micas

Micas constitute a group of minerals which contain silicate of alumina with a silicate of one or more of the following bases:—potash, soda, iron or magnesia. The micas have a tendency to form thin flakes and in the muscovite variety they are stable and resist decomposition but in the biotite variety the flakes decompose comparatively easily. The micas ultimately give silicate of alumina, oxides of iron and carbonates of the other bases.

Zeolites.

Zeolites are silicates of alumina, potash and lime. They are in abundance in certain parts of the Deccan trap but in the soils in general they may not be present in large amounts. They are many times formed by alteration in felspars. They contain water and their peculiarity is that the calcium, potassium, sodium &c. which they contain are displaced by other metals when their salts are brought in contact with zeolite powder. It is supposed that zeolitic bodies in the soils help in retaining some of the mineral manures.

Calcite.

Calcite and limestone are abundant in nature. Their composition is calcium carbonate. They are easily attacked by water containing

carbon dioxide. Lime is essential as a plant food, and its agricultural importance arises also from its effect in altering the texture of soils and in modifying the chemical changes attending decay of organic matter. The presence of calcium carbonate acting as a base is essential to the important process of nitrification. Dolomite is a double carbonate of lime and magnesia and resembles limestone in its decomposition.

Gypsum.

Gypsum is calcium sulphate. It is slightly soluble in water and mechanically it is easily reduced to powder. It improves the physical condition of the soil when added at the rate of about 200 lbs. per acre. It also helps nitrification.

Iron oxides.

Iron oxide is essential in soil for proper plant growth but it is seldom wanting in the soil. It is generally present as limonite. The red and brown colours of soils are due to the presence of iron.

Soil-forming Rocks.

All the rocks of the earth crust when disintegrated and decomposed from soils. Yet there are certain rocks which are typical and which occupy large areas and it is these rocks which might be taken as the chief sources of the different soils. They are :—Granite, diorite, gneiss, trap, sandstone. shale, limestone, laterite and alluvial material. The soil resulting from a rock is determined by the minerals of which the rock is made. Sometimes soils derived from rocks of the same name differ in their qualities. This happens because although the rocks may contain the same minerals yet they may be present in different proportions. For instance a granite may consist mainly

of felspar and quartz with a small quantity of mica or it may consist mainly of quartz and mica with a small quantity of felspar. Notwithstanding such variations, a fairly approximate general estimate of the qualities of the soils can be made by the study of the decomposition of rocks.

Granite soils.

Granites ordinarily consist of potash felspar, quartz and mica. The soils derived from granites, therefore, have generally enough of potash and a very small quantity of lime. If hornblende is present in the place of mica or is a secondary mineral lime also is found to be in good quantity. Sometimes apatite is found as a secondary mineral which is then able to supply both lime and phosphoric acid. By mechanical disintegration the felspar is reduced to clay but the quartz breaks down very slowly and therefore the soil may be a mixture of very fine clay full of large particles of quartz. If the land is sloping the clay is easily washed down into the valley. The soils at the higher level are of coarse quartz particles and therefore not fertile while the soils in the valley containing only cold stiff clay are difficult for cultivation.

Diorite

Diorite is made up of felspar and hornblende. Although hornblende disintegrates slightly more quickly than felspar yet the material produced is of the same size of particles and hence there is no separation of the decomposition products from these two minerals. The soils contain generally enough of lime and potash.

Gneiss soil.

The term gneiss refers more to the structure of the rock than to its constituents. In India most of the gneisses have the same compo-

sition as the granites and hence the soils derived from them are like those of granite origin.

Trap soils. The trap rock consists essentially of felspar, hornblende or augite, magnetite and sometimes olivine. The disintegration of the important minerals like felspar and hornblende is fairly uniform. Between themselves the two minerals supply the necessary quantities of potash, lime, magnesia and small quantities of other ingredients. In granites, felspar is the only source of clay but in the trap both felspar and hornblende yield clay. The soils produced from trap are generally more productive than the soils derived from granites. A granite soil, in addition to the sand will consist of kaolin (forming clay) and potash from its felspar. A trap soil in addition to the siliceous matter kaolin and potash from its felspar will generally contain, lime, magnesia and iron oxides derived from its hornblende. It therefore yields more substances required for vegetable life than granite.

Sand-stone soils. It is sometimes difficult to speak of the qualities of a sandstone soil without studying the original sandstone with regard to the minerals present in it. In the humid regions the sandstone soils are generally poor because they mainly consist of quartz grains, the rest of the minerals being easily decomposed are removed by washing. In an arid region on the other hand these minerals are not removed by washing and they form grains which look as hard as those of quartz but yield plant food when they are acted upon by water. Such soils, therefore, prove to be productive when irrigated. In giving an opinion on the

sandy soils the original sandstone and the climatic conditions of the locality must be carefully considered. All sandstone soils are, however, open, porous and easily workable or "light" as they are many times called.

Shale soils

Shales consist of finer particles than sandstone. The soils derived from them are more retentive of water than sandstone soils but less retentive than clay soils. They generally contain enough of potash but are poor in lime and phosphoric acid. These soils respond to manures.

Limestone soil

Soils derived from limestones are rich in lime and are clayey. Many times they may prove to be impervious and they may be wanting in potash and phosphoric acid. If these soils get mixed with soils derived from other rocks they yield good crops.

Laterite soils.

The laterite itself is formed by a peculiar weathering by which silica, alkalies and lime &c. are washed away and consequently there is an increase in the iron and alumina. Laterite soils are generally red and many times deficient in some of the plant food constituents. They are light, porous and many times hungry. They are therefore not fertile soils. If, however, the laterite soils get mixed with materials, especially clayey materials—derived from other rocks they give excellent crops.

Transported soils

The rich alluvial soils contain inorganic materials which have been transported from a distance by water currents. The materials in many cases are derived from various rocks and the re-

sulting soil, therefore, possesses greater fertility than any soil formed exclusively by the decomposition of one kind of rock. Transported soils have generally sufficient plant food constituents and they are in such a condition that they are available to plants. These soils are generally well drained.

CHAPTER VII

SOILS OF INDIA.

Out of the various rock formations of India there are three which occupy very large areas and it is on this account that the soils derived from these formations cover a vast area of the Indian land. The soils may be classified into three main groups as follows:—(1) Soils derived from granites and gneisses, (2) Soils derived from the Deccan trap, both of which occupy the peninsular area and (3) The alluvial soils mostly made up of the Indo-Gangetic alluvium.

Solis from Granites and gneisses.

Soils derived from the granites and the gneisses occupy a very large area. They cover the eastern and southern parts of the Peninsula including most of the Madras Presidency, Mysore state and the southern part of the Bombay Presidency. They occupy a large part of Hydrabad state, the Central Provinces, Orissa and Chota Nagpur. The soils vary very much. On the arid uplands they are thin, light coloured and stony. Such soils are poor in their yield. On the low lands they are some times very clayey and yield good crops only when there is good and heavy rain. The red and red-brown soils of clayey character found on fairly level land are fertile. Medium soils of good depth can be irrigated with advantage. In southern India rice is grown on such soils with irrigation where it is availabe. Under tank and well

irrigation which is extensive in certain parts, a great variety of valuable crops are grown. The soils in the southern part of the Bombay presidency, which are derived from granites and gneisses are found in the Belgaum, Dharwar and North Kanara Districts. They are sometimes mixed with soils from laterite or schists of various types. Where they are clayey they are yellowish, red or brown. They are fertile and in well drained situations grow a great variety of crops. They grow rice, in the low-lying fields, in other places fruit trees grow well. The light coloured soils are generally poor. The soils described above are in most cases deficent in phosphoric acid, nitrogen and organic matter.

Trap soils.

The second rock formation which occupies a large area in the Peninsula is the Deccan Trap. The trap soils are therefore found over vast areas especially in the Bombay Deccan, Berar, the Western third of the Central Provinces and the Western half of the Hydrabad state. The soils throughout this area vary to a great extent in character and productiveness. On the uplands and on the slopes the soils are light coloured, thin and poor. On the low lands and in the valleys deep relatively clayey soils are found which grow excellent crops of *jowar* or wheat under favourable rain conditions. Along the *Ghats* rice is common on embanked and terraced soils. Medium black soils are good for fruit culture and for vegetables under irrigation.

Black cotton soil is a term applied to a deep black clayey soil found generally below the level of the foothills. It is formed by the washing of the disintegrated material from a higher level. In the third volume of the

Imperal Gazetteer the black cotton soils are described as follows:—"Black cotton soil occurs within the area of the Deccan trap in undulating or sloping situations, below the general level of the foot-hills. It varies in depth according to position and, where very deep, has been accumulated by alluvial deposit. In places in the valley of the Tapti, the Narbada, the Godavari and the Krishna heavy black soil is often 20 feet in depth. Owing to its dense consistency it becomes unworkable during heavy rains, and in these places, is better adapted for *rabi* crops of wheat, linseed, gram &c. than for cultivation in the *Kharif* season. The black cotton soil of the Deccan trap area which grows cotton and *jowar* as staple crops in the *Kharif* season, is as a rule, only three or four feet deep and is mixed with nodular pieces of limestone and small fragments of disintegrated trap. The subsoil contains a good deal of lime being shaly, allows free drainage to the trap rock below. Black soils vary in colour, consistence, and fertility, but all are highly retentive of moisture. In the hot weather shrinkage due to evaporation causes the formation of numerous craks which are often several feet deep. This feature has given origin to the common saying. " Black soil ploughs itself ". The deeper black cotton soils are entirely unsuitable for irrigation; but the mixed black soil found in the smaller valleys, when it is of moderate depth and the substratum affords good natural drainage, admits of well irrigation and produces under liberal cultivation all kinds of garden crops. The depth to the subsoil water in these situations is usually 25 to 32 feet. Outside the Deccan trap area the black cotton soil predominates in Surat and Broach districts.

"Pure black cotton soil is generally known as *regar* and it is believed that percentages of soluble silicates, iron and alumina which it contains, are fairly constant within moderate limits. The amount of magnesia is also very constant. Lime varies in amount and also in the form in which it is found. It occurs usually both as carbonate and as silicate. Magnesia is always present in high proportion. The quantity of potash varies considerably, but it is not usually defective. The amount of phosphoric acid, nitrogen and organic matter is usually or frequently low".

Indo-Gangetic Alluvium.

In India the alluvial tracts are very extensive and they form the most fertile areas. The most important alluvial tract in expanse is the Indo-Gangetic plain. This plain extends from Sind in the west to Bengal in the east and thus occupies the whole of Northern India. It covers Sind, Gujérat, Rajputana, the Punjab, the United Provinces and Bengal. There are other alluvial tracts besides the Indo-Gangetic plain. These are the Godavari, Krishna and Tanjore Districts, strips of alluvial material along the eastern and the western *ghats* and also along the courses of the various rivers in the Peninsula.

The soils of the Indo-Gangetic plain vary in colour from ash to brown. In their consistency also they vary from coarse sands to clayey soils sometimes so sticky as to be impervious. The alluvial soils of other tracts are dark coloured loams. The amount of nitrogen and organic matter in the alluvial soils is generally low, phosphoric acid though deficient is better than in other

soils. Potash is adequate while lime is present in large quantities. The proportion of iron and alumina also is high.

The Punjab soils.

The soil of the Punjab alluvial loam, is generally sandy and fairly uniform in character. There are local differences howover, the soil of the Lower Bari Doab canal colony being, for example, a heavier loam than that of the Lower Chenab canal colony.

The U. P. soils.

In the United Provinces the Indo-Gangetic soil shows little variation in chemical compotion and even with regard to structure and the size of particles the differences are not pronounced. Even those soils which are locally considered as clays contain a considerable proportion of sand. The soils have sufficient lime and potash but they are poor in phcsphoric acid and nitrogen.

Bihar and Orissa soils.

North Bihar is a level plain falling gradually from the foot of the Hymalayas but with a belt of fairly high land along the bank of the Ganges. The soil consists mostly of the older alluvium or *bangar* of the Gangetic plain, which is a yellowish clay with Kankar. The low lands are composed of recent deposits of sand and silt brought down by small rivers during flood time. This recent alluvial is very retentive of moisture.

Bengal soils.

In Bengal the soils are all of Indo-Gangetic alluvium. There are as everywhere else local differences. The old alluvium of Rajashahi and Burdwan divisions is a stiff and intractable soil, not very retentive of moisture, whilst the alluvial land in Western Bengal is usually loamy and fairly easy to work.

CHAPTER VIII.

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SOILS OF THE BOMBAY PRESIDENCY.

The soils of the Bombay Presidency can conveniently be considered according to the divisions. Beginning from Sind which is the Northernmost division of the Bombay Presidency and which is covered with the recent formation of the Indo-Gangetic alluvium we might proceed southword towards the Karnatic which is the southernmost part of the Presidency and is covered with the oldest rock formation.

Sind soils.

Sind consists of the valley of the lower Indus and comprises three distinct tracts—the Kohistan, or hilly country, on the extreme west, the central alluvial plain, watered by the Indus and the Thar, or desert, on the eastern boarder. The central plain is the most important portion. The soils of this portion are entirely alluvial. They vary in character from drift sands to stiff clays. In some places the soil is very rich especially where tracts are covered with silt-laden waters.

The alluvial tracts on each side of the Indus are annually submerged in the inundation season and large areas which are covered by spilt-water retain sufficient moisture after the flood subsides to grow good crops without irrigation. The silt deposited by canal water on arable fields is of immense value. It enriches the soil. These soils have sufficient lime, potash and phosphoric

acid and even nitrogen under proper cultivation. At some places the Sind soils show formation of salt incrustation on the soils making them unfit for cultivation. These soils are called *Kalar*. The salts are not due in many cases to water-logging but are due to the downward and upward movement of water, which leaves the dissolved salts behind on evaporation. It is only in a few cases that the *Kalar* is developed due to water-logging.

Gujerat soils.

Gujerat can be divided into three tracts according to the soils it contains. These are :—(1) The Panch Mahal tract, (2) The Northern Gujerat tract and (3) The Southern Gujerat tract.

The Panch Mahal tract stands by itself in the alluvial land of Gujerat. The predominent rocks there, are granites and gneisses and therefore, as expected the soils are light coloured, shallow, and poor, while in the low-lying areas, deep, rich dark coloured loams, retentive of moisture are common. These soils can give two crops in a year, Usually there is maize in the *Kharif* season and wheat in the *rabi* season.

In the north Gujerat tract consisting of Ahmedabad and Kaira districts the soil is alluvial of the Indo-Gangetic type and is called *Goradu* soil. *Goradu* soils are characterised by immense depth. They are distinctly sandy in character, varying from drift sands of the Ahmedabad district to the rich loams of Kaira and Borsad. They vary in colour from light ash to rich brown. These soils do not crack. They are very suitable for irrigation and much of the best well irrigation of the Presidency is on this land. Along the rivers there are soils called *Bhatha* formed from silt.

The Southern Gujerat tract comprises the Broach and Surat districts. The soils of this tract are the (1) deep black soils, (2) the *bhatha* soils, (3) the *Gorat* soils and (4) the *Kiari* soils. All these soils are of alluvial character. They are however not of the Indo-Gangetic type. The main source of the deep black soils of Broach and Surat is trap with a little granite or gneiss. The colour of the soils is black and they are very deep. They are the black cotton soils which are already described. They are also known as *regur*. The *bhatha* soils are red, brown or chocolate in colour. They are alluvium deposited by rivers during high flood. The fertility of these soils may be renewed every year by fresh silt. These soils are found in belts along the Tapti and Narbada banks. The *bhatha* soils grow excellent irrigated crops. Old *bhatha* soils are found sometimes away from the present rivers. They are called *gorat* soils. They are alluvial in character and are suited for irigation. *Kiaris* are rice soils in low-lying areas, receiving drainage from the surrounding country.

The Deccan tract soils

The Deccan is made up of the following Districts :— East and West Khandesh, Nasik, Poona, Satara, Ahmednagar and Sholapur. The soils of all these districts are entirely derived from trap. The Khandesh soils form one group and the rest of the Deccan has three Northsouth strips of soils parallel to the Western Ghats.

The Khandesh soils are black cotton soils and hence they are generally very deep and retentive especially those that form the flat areas along the Tapti river. The crops taken on these soils are cotton, *jowar* and wheat.

The detailed description of black cotton soils has already been given and hence need not be repeated here. The remaining portion of the Deccan districts may be divided into (1) The high lying strip along the western *Ghats*-hilly in character with heavy rain-fall and having soils of a very shallow character. On these soils rice and small millets are grown on terraces. (2) A strip of country which is less hilly, and has sufficient and certain rainfall is the second. Soil in this part is not very deep. Both *kharif* and *rabi* crops as also irrigated crops are taken in this strip, (3) The third is the eastern most strip of the Deccan which has uncertain rainfall. This part has got deep black soils which are retentive and with enough rainfall they give excellent crops. The wheat lands of Nasik and of Kopargaon in Ahmednagar, *rabi jowar* lands of Ahmednagar and Sholapur, are black soils. The divisions of soils shown above are very rough. These soils are all from trap. They simply indicate the stage of decomposition of the rock and the nature of accumulation of the soil. Even in one village we may meet with all types of soils.

Near the *Ghats* the proportion of the shallow soils will be great with only a small area, if at all, under black soils while in the eastern strip the proportion of the black deep soils will bear a high proportion to the shallow soils.

There are soils found on the river banks which are suitable for garden crops. Along the canals in some places salt lands have developed in recent years. The cause is invariably the rise of subsoil water which is not drained away on account of impervious layers at depths varying from a foot or two to seven or eight feet. The

salt lands are unfit for cultivation as the salts prove to be poisonous to plants.

In some parts of Ahmednagar and Sholapur districts numerous round stones of varying size are found in the fields. The soils in which these stones are found are fine in texture and fairly fertile. The stones are brought up by tillage. They slowly decompose into soil and are in no way troublesome to the crop.

The Konkan soils

Thana and Kolaba districts have trap soils. Ratanagiri has laterite soils. On the northern side the laterite is over the trap while on the southern side it is over the gneiss. Soils of North Kanara are derived from a variety of rocks. The whole Konkan is hilly and has thin and porous soils. Near the coast we meet with some deeper soils on level land. The soils in general are divided into (1) *Varkas* soils, (2) rice soils and (3) garden soils.

The *Varkas* soils occupy the uplands. They are very thin and poor. They are allowed to waste periodically. After the rest there is a rolation of crops. Inferior millets, niger &c. are the usual crops.

Rice soils which are low-lying and rich are called *mala* while those which are on the uplands and slopes with terraces are of a poorer character. They are known as *Kuryat*. There are some lands recovered from sea. They are saltish and therefore people grow salt-rice on such lands. They are called *Kharvat*.

Garden lands are found along the coast in the Thana district. They have light easily workable soils. Various kinds of garden crops are grown on them. Practically there are no deep clayey soils along the coast line and at

many places garden crops can be grown if water in good quantity is available.

North Kanara is the southernmost district of Konkan. On the top of the *Ghats* and uplands the soil is laterite. Much of the land is under forest. Rice is grown where land has been cleaned. In the valleys between hills there are gardens growing belet nut, cardamom and pepper &c. The soils of these gardens are derived from shales. Where these valleys open out rice is the chief crop grown. The coast line is covered with soil derived from low-level laterite or decomposing gneisses. The soils of the North Kanara vary from yellowish to red in colour. They are well drained and porous and in places very hungry. They are poor in lime and phosphoric acid.

Karnatak soils

Three districts are included in Karnatak—Belgaum, Dharwar and Bijapur. The Belgaum district has granite and gneiss formation on its southern side where it meets the boundaries of Dharwar. and North Kanara, sandstone formation in its eastern part where it meets Bijapur, on the northern and western side it has trap, in many places coverd with laterite. The soils of the Belgaum district naturally vary very much. The soils derived from only laterite or sandstone are very porous and also poor. Where the laterite or sandstone soils are mixed with trap soils they make a very good mixture and produce excellent crops. Near Belgaum the soils are formed by a mixture of material derived from both the laterite and trap. These soils are rich, and grow rice and all sorts of vegetables. They are very good for irrigated crops.

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